PATENT SPECIFICATION (11) 1 596 648

1 596 648

(21) Application No. 52032/77 (22) Filed 14 Dec. 1977 (19)
(31) Convention Application No's 752199 (32) Filed 20 Dec. 1976
785347 7 Apr. 1977
825670 18 Aug. 1977 in
(33) United States of America (US)
(44) Complete Specification Published 26 Aug. 1981
(51) INT. CL.^{3} G01N 27/18
(52) Index at Acceptance
G1N 1A3B 1A3C1 1D13 1F 3S1A 3S2 7A1
AHE

(54) APPARATUS FOR DETECTING THE PRESENCE OF AN IMMISCIBLE FOREIGN LIQUID ON THE SURFACE OF A DESIRED LIQUID

(71) I, BRONSON MURRAY POTTER, a citizen of the United States of America, of Hurricane Hill Road, Greenville, State of New Hampshire, 03048, United States of America, do hereby declare the invention, for which I pray that a patent may be granted to me, and the method by which it is to be performed, to be particularly described in and by the following statement:-

This invention relates to apparatus for detecting the presence of an immiscible foreign liquid on the surface of a desired liquid. The apparatus can be used for example for detecting oil spills on water.

According to the present invention, there is provided apparatus for detecting the presence of an immiscible foreign liquid on the surface of a desired liquid, when the two liquids have different heat absorptive properties, e.g. oil on the surface of water, the apparatus comprising a monitoring element exposed for heat transfer contact with a liquid when immersed therein, said monitoring element being capable of dissipating electrical power and having an electrical characteristic that changes as a function of temperature, a restorative electrical circuit connected to said monitoring element to supply electrical power to the element to be dissipated thereby and responsive to changes in said characteristic of the element to adjust said supply of electrical power to counteract said changes, indicating means responsive to said changes to provide an indication of changes in the rate of heat loss from the element, and probe means adapted to position said monitoring element at the surface of a body of the desired liquid so as to be immersed in any foreign liquid on the surface. By "different heat absorptive properties" it is meant that identical bodies at the same initial temperature would lose heat at different rates. This difference may be due to heat conduction differences or differences in convection resulting from differences in viscosity of the two liquids. The restorative electrical circuit tends to keep the operating temperature of the monitoring element between design limits or, in some embodiments, substantially constant, thereby reducing the possibility of the element burning out or igniting a volatile liquid.

In some embodiments, the restorative electrical circuit includes reference means representing a predetermined value of said electrical characteristic of the device and the circuit is operable to restore the actual value of said characteristic towards said reference value. Then, said indicating means may be responsive to changes in said supply of electrical power required to restore said characteristic value.

In preferred embodiments, the apparatus includes a further said monitoring element, and means to position said further element beneath the surface of the body of the desired liquid so as to be immersed in the desired liquid, said restorative circuit being connected also to said further element and arranged to counteract changes in the electrical characteristic of the further element, said indicating means being responsive to differential changes in the characteristics of the two elements. Then, in one arrangement, the restorative circuit is operable to restore the actual values of the two elements independently towards said reference value, and the indicating means is responsive to differential changes in said supply of electrical power to the two elements required to restore said characteristic values.

In another arrangement, said two elements are connected in a network to be supplied jointly with electrical power and the restorative circuit is responsive to changes in the combined said characteristic of the network due to changes in the characteristic of each of the elements to adjust said supply of electrical power to counteract said combined changes.

Normally, the electrical characteristic is resistance and then the restorative circuit conveniently includes a resistance bridge with the first mentioned said element in one arm of the bridge and electrical power regulator means responsive to imbalance in the bridge to control the supply of power to the bridge to bring the bridge back towards balance. Then in said one arrangement, the restorative circuit may include a further resistance bridge with said further element in one arm and a further said electrical power regulator means to control power to said further bridge, said indicating means being responsive to the difference in the voltages across the two bridges.

In the other arrangement, the network including the two elements may be connected in said one arm of the bridge. Then, preferably, said network is an ancillary bridge and said indication means is responsive to changes in the balance of the bridge due to differential changes in the resistances of the two elements.

The monitoring element or elements may be thermistors or filaments of metal with a positive temperature coefficient of resistance such as tungsten.

In another preferred embodiment the network of thermistors is connected in series with a temperature-independent reference resistor in an electronic energising circuit. Because of the series connection, the same current flows through the reference resistor and the network. Connected across the reference resistor and across the network are the inputs to separate operational amplifier means whose outputs are measures of the voltage across the reference resistor and the network and are also measures of the respective resistance values. A further operational amplifier means is disposed in the circuit so that its input is the difference between the outputs of the operational amplifier means whose inputs are connected across the network and reference resistor. The output of this further operational amplifier means is proportional to the difference in resistance between the series network and the reference resistor, and is used to regulate the power flow through the network in a manner tending to maintain the resistance of the network equal to the resistance value of the reference resistor.

The probe means may comprise a float adapted to float freely on the surface of the body of the desired liquid with said element mounted therein so as to be just under the uppermost liquid surface.

The further element may also be mounted in the float at a greater depth beneath the uppermost liquid surface and normally immersed in the desired liquid.

Embodiments of the invention will now be described in conjunction with the following drawings in which:

Figure 1 is a schematic diagram of the circuitry of a preferred embodiment of the invention employing a series connection of two thermistors;

Figure 2 is a schematic diagram, similar to Figure 1, of an embodiment of the invention employing a parallel connection of two thermistors;

Figure 3 is a schematic diagram of circuitry of an embodiment of the invention employing operational amplifiers;

Figure 3a is a schematic diagram of circuitry of an embodiment of the invention employing one operational amplifier;

Figure 4 is a diagrammatic view of an oil detection float having two thermistors and employing the circuitry of Figure 1 or Figure 2;

Figure 5 is a schematic diagram of an embodiment of the invention employing a constant current circuit and a negative temperature coefficient thermistor; and

Figure 6 is a schematic diagram of circuitry combining two of the thermistor circuits of Figure 1 in a summing arrangement using single thermistors in the sensing legs.

Referring to Figure 1, transistor Q_1, a five-watt silicon transistor with β over 100, operates as a standard series regulator. Transistor Q_2, a standard NPN entertainment transistor with β over 100, serves to modify transistor Q_1's base current in response to the current flow between the base and emitter of transistor Q_2 caused in turn by a resistance imbalance in the resistance comparing bridge circuit shown. Two arms of this bridge are formed by 1000 Ω resistors R_1 and R_2; the other arms are formed by a 190 Ω reference resistor R_3 and ancillary bridge comprising the series connections of the two thermistors T_1 and T_2 in parallel with series-connected resistors R_4 and R_5. Thermistors T_1 and T_2, both Fenwal GD31SM2, have negative temperature coefficients. Resistors R_4 and R_5 are each 1000 Ω. The base and emitter of transistor Q_2 are connected to the midpoints of the resistance comparing bridge circuit. The diode D is a standard milliwatt device which compensates for the forward potential between the base and emitter of transistors Q_2. At 25°C ambient temperature conditions, the thermistors T_1 and T_2 each have a resistance of 1000 Ω.

In operation, whenever the resistance comparing bridge of Figure 1 is unbalanced, a potential difference developes between points A and B. When the resistance of the ancillary bridge is higher than the reference resistor, transistor Q_2 is turned off allowing

transistor Q_1 to be fully on. Power, therefore, flows through the ancillary bridge to ground causing heating of the thermistors and an attendent decrease in their resistance values. Power will continue to flow until the resistances of thermistors T_1 and T_2 change, thereby reducing the potential difference between A and B and bringing the bridge into balance. Transistor Q_2 then begins to turn on, robbing transistor Q_1 of some of its base current, thereby turning it partly off. As transistor Q_1 progressively turns off the current flow through the ancillary bridge is reduced. Thus, this restorative electronic circuit attempts to maintain the resistance of the ancillary bridge, consisting of the series-connected thermistors and resistors R_4 and R_5, equal to the resistance of the reference resistor R3 in the face of changing conditions in the surrounding medium.

Whenever thermistors T_1 and T_2 are exposed to a surrounding medium such that the rate of heat loss from each of the thermistors is the same, the ancillary bridge R_4 and R_5 will be balanced; the voltage as measured by voltmeter V will be zero. If, for example, the temperature of the surrounding medium were to change, the resistance values of thermistors T_1 and T_2 will change. The resistance comparing bridge will then become unbalanced and the restorative electronic circuit will adjust the power flow through the ancillary bridge to restore balance. The output voltmeter V will continue to read zero, however, since the temperature of thermistor T_1 remains equal to the temperature of thermistor T_2, even though the flow of power through the thermistors will have changed. Temperature compensation has been achieved very simply by putting the two thermistors in the same arm of the main bridge circuit. When, however, the temperatures of thermistors T_1 and T_2 differ, as, for example, when one thermistor is exposed to a still fluid and the other to the same fluid in motion, the ancillary bridge becomes unbalanced and a voltage will register on the voltmeter V indicating the velocity of the fluid in motion.

In the similar embodiment shown in Figure 2, thermistors T_1 and T_2 are connected in parallel within the ancillary bridge having arms T_1, T_2, R_4 and R_5. Its operation is similar to the embodiment of Figure 1. Only when the temperatures of thermistors T_1 and T_2 differ will voltmeter V register.

Figure 3 is an embodiment of the invention embodying operational amplifiers. Operational amplifier 10 is connected across reference resistor R_1 and serves as a gain of one inverter amplifier, with its output proportional to the voltage across resistor R_1. Operational amplifier 11 is connected across the ancillary bridge having arms T_1, T_2, R_9 and R_{10} and serves as a gain of one amplifier with its output proportional to the voltage across the ancillary bridge. The two outputs are electrically subtracted and the difference serves as the input to operational amplifier 12, which serves as a gain of ten summing amplifier, with its output proportional to the difference in the voltages across the ancillary bridge and reference resistor R_1. Because the current flow through the ancillary bridge equals that through reference resistor R_1, the output of operational amplifier 12 is proportional to the difference in resistance between the ancillary bridge and reference resistor R_1. The output signal from operational amplifier 12 is connected to the base of transistor Q thereby controlling the flow of power through the ancillary bridge and controlling its resistance. Voltmeter 16 is connected across the ancillary bridge to indicate the difference in resistance between thermistors T_1 and T_2.

In this embodiment the frequency compensation and power supply connections to the operational amplifiers (routine to the art) are not shown. The following components are used:

Thermistors T_1 and T_2	Fenwal GD25SM2
series regulator Q	2N1038
operational amplifiers 10,11,12	709
resistances:	
R_1	33 K Ω
R_2	2.7K Ω
R_3	2.7K Ω
R_4	2.7K Ω
R_5	2.7K Ω
R_6	10 K Ω
R_7	10 K Ω
R_8	330 K Ω
R_9	1000 Ω
R_{10}	1000 Ω

Figure 3a shows an embodiment of the invention similar to Figure 1 in which transistor Q_2 of Figure 1 has been replaced by operational amplifier 12 whose output is a measure of the main bridge unbalance. This output controls the power flow through the sensing leg via transistor Q_1.

Figure 4 shows the invention embodied as an oil detection unit employing the circuit of Figure 1 or 2. The oil detection system includes a buoyant, tubular housing 50 designed to float on water 52 to be monitored. Housing 50 has upper and lower recesses 54, 56. The buoyancy of housing 50 is such that recess 54 is disposed at the surface of the water and recess 56 is submerged. Reference thermistor 20 is disposed in recess 56 so that it remains under water. Sensing thermistor 22 is disposed in recess 54 at the air-liquid interface so that it is exposed to oil should a film of oil 24 exist on the monitored surface. The oil detection unit may be self-contained and include batteries 30 (which function as ballast), the electronic circuit of Figure 1 or 2, 32, and an output indicator 34 on its upper surface. In another embodiment, the unit may be connected by flexible cable (not shown) to a remote power supply and to remote output indicator circuitry.

Figure 5 is an embodiment of the invention employing a constant current circuit which attempts to maintain a constant current flow through collector resistor R_1. There are two parallel paths for current to flow from the energy source to ground, one through resistor R_1 and transistor Q_1 and the other through resistor R_1, thermistor T and R_2. Thermistor T is connected between the base and collector of transistor Q enabling transistor Q to control the flow of current through thermistor T. The component values are chosen so that the circuit keeps current through T constant thereby tending to restore a predetermined resistance value, however imperfectly. If conditions change in the surrounding medium such that thermistor T cools, for example, its resistance increases causing the potential at the base of transistor Q to fall, progressively turning transistor Q off, thereby allowing more current to flow through the thermistor T. This increased power through thermistor T heats it, causing its resistance to decrease. Voltmeter V measuring the voltage across the thermistor is an indication of the heat transfer from the thermistor to the surrounding medium. For a positive temperature coefficient thermistor, the positions in the circuit of thermistor T and voltmeter V are exchanged with that of resistor R1.

Referring to Figure 6, two of the circuits of Figure 1 are shown connected in a summing arrangement using single thermistors in the sensing legs. One of the thermistor circuits acts as a reference. Whenever the power flow through thermistor T_1 differs from the power flow through thermistor T_2, an output signal develops on leads ℓ_1 and ℓ_2. If, for example, thermistor T_2, the reference, is exposed to water, and thermistor T_1 is exposed to water with a small amount of alcohol added, the power required to maintain the two thermistors at a constant, preselected temperature will differ because of the different heat transfer characteristics of the two fluids. An output signal will therefore develop on leads ℓ_1 and ℓ_2 from which the presence of an adulterant can be inferred. For certain applications the reference circuit need not be another thermistor circuit; it may consist of a simple resistance circuit to serve as a reference.

While the preferred devices used to perform the thermistor functions of this invention are those semiconductor units sold as "thermistors," it will be understood that certain features of the invention can be obtained using other devices, or combinations whose effects upon the circuit varies with temperature in a single valued relation. For instance, a temperature sensitive diode or transistor may be employed in certain instances, provided its temperature characteristic corresponds to the needs of the particular application involved. Also, a metallic filament, such as tungsten, whose resistance is temperature dependent may be employed.

WHAT I CLAIM IS:

1. Apparatus for detecting the presence of an immiscible foreign liquid on the surface of a desired liquid, when the two liquids have different heat absorptive properties, e.g. oil on the surface of water, the apparatus comprising a monitoring element exposed for heat transfer contact with a liquid when immersed therein, said monitoring element being capable of dissipating electric power and having an electrical characteristic that changes as a function of temperature, a restorative electrical circuit connected to said monitoring element to supply electrical power to the element to be disspiated thereby and responsive to changes in said characteristic of the element to adjust said supply of electrical power to counteract said changes, indicating means responsive to said changes to provide an indication of changes in the rate of heat loss from the element, and probe means adapted to position said monitoring element at the surface of a body of the desired liquid so as to be immersed in any foreign liquid on the surface.

2. Apparatus as claimed in claim 1, wherein the restorative electrical circuit includes reference means representing a predetermined value of said electrical characteristic of the device and the circuit is operable to restore the actual value of said characteristic towards

said reference value.

3. Apparatus as claimed in claim 2, wherein said indicating means is responsive to changes in said supply of electrical power required to restore said characteristic value.

4. Apparatus as claimed in any preceding claim and including a further said monitoring element, and means to position said further element beneath the surface of the body of the desired liquid so as to be immersed in the desired liquid, said restorative circuit being connected also to said further element and arranged to counteract changes in the electrical characteristic of the further element, said indicating means being responsive to differential changes in the characteristics of the two elements.

5. Apparatus as claimed in claim 4 as dependent on claim 3, wherein the restorative circuit is operable to restore the actual values of said two elements independently towards said reference value, and the indicating means is responsive to differential changes in said supply of electrical power to the two elements required to restore said characteristic values.

6. Apparatus as claimed in claim 4 as dependent on claim 1, wherein said two elements are connected in a network to be supplied jointly with electrical power and the restorative circuit is responsive to changes in the combined said characteristic of the network due to changes in the characteristic of each of the elements to adjust said supply of electrical power to counteract said combined changes.

7. Apparatus as claimed in any preceding claim wherein said electrical characteristic is resistance and the restorative circuit includes a resistance bridge with the first mentioned said element in one arm of the bridge and electrical power regulator means responsive to imbalance in the bridge to control the supply of power to the bridge to bring the bridge back towards balance.

8. Apparatus as claimed in claim 7 as dependent on claim 5, wherein the restorative circuit includes a further resistance bridge with said further element in one arm and a further said electrical power regulator means to control power to said further bridge, said indicating means being responsive to the difference in the voltages across the two bridges.

9. Apparatus as claimed in claim 7 as dependent on claim 6, wherein the network including the two elements is connected in said one arm of the bridge.

10. Apparatus as claimed in claim 9 wherein said network is an ancillary bridge and said induction means is responsive to changes in the balance of the bridge due to differential changes in the resistances of the two elements.

11. Apparatus as claimed in claim 10 wherein the elements are in respective series connected arms of the ancillary bridge.

12. Apparatus as claimed in claim 10 wherein the elements are in respective parallel connected arms of the ancillary bridge, connected together at one end.

13. Apparatus as claimed in any preceding claim wherein the monitoring element or at least one of the elements is a thermistor.

14. Apparatus as claimed in any of claims 1 to 12 wherein the monitoring element or at least one of the elements is a filament of metal with a positive temperature coefficient of resistance.

15. Apparatus as claimed in claim 14 wherein the metal is tungsten.

16. Apparatus as claimed in any preceding claim wherein the probe means comprises a float adapted to float freely on the surface of the body of the desired liquid with said element mounted therein so as to be just under the uppermost liquid surface.

17. Apparatus as claimed in claim 16, as dependent on claim 4 or any of claims 5 to 15 when dependent (directly or indirectly) from claim 4, wherein said further element also is mounted in the float so as to be at a greater depth beneath the uppermost liquid surface and normally immersed in the desired liquid.

18. Apparatus for detecting the presence of an immiscible foreign liquid on the surface of a desired liquid substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

BOULT WADE & TENNANT,
27 Furnival Street,
London EC4A 1PQ.

Printed for Her Majesty's Stationery Office, by Croydon Printing Company Limited, Croydon, Surrey, 1981.
Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

FIG 1

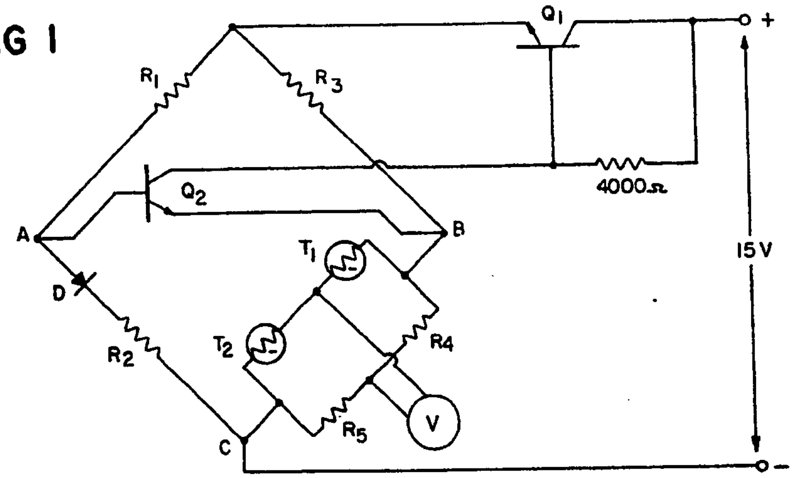
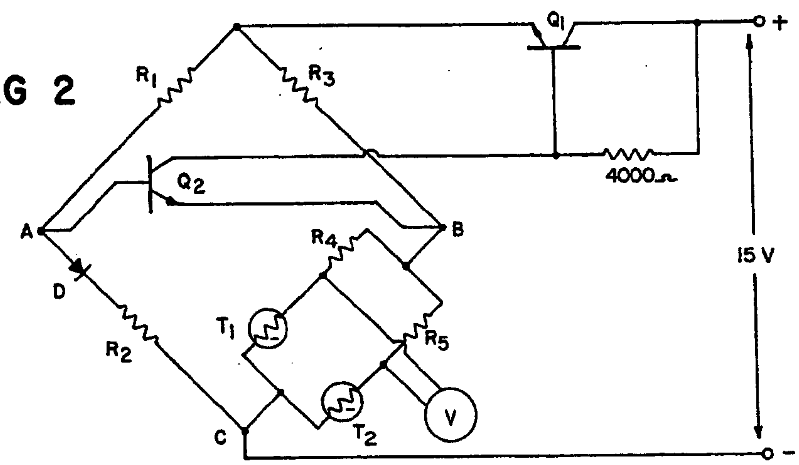


FIG 2



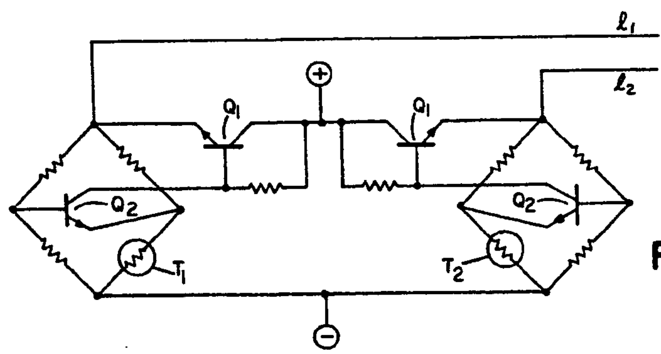


FIG. 6

FIG 3a

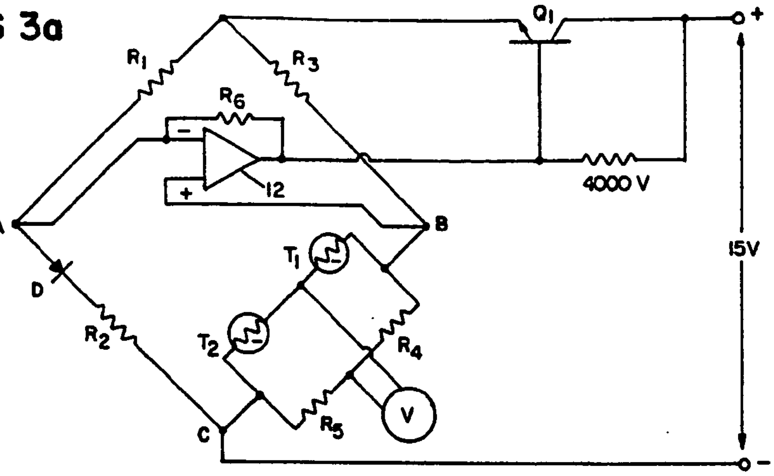
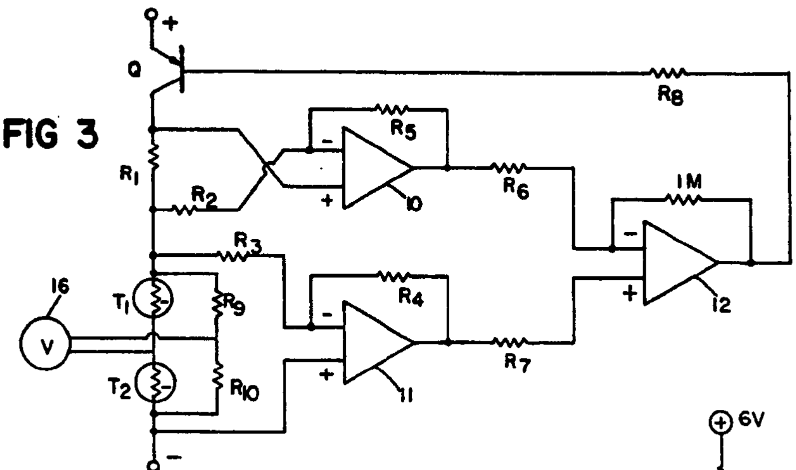


FIG 3



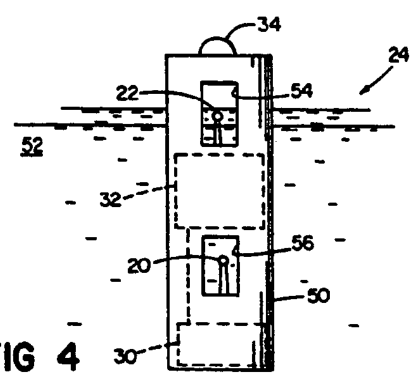


FIG 4

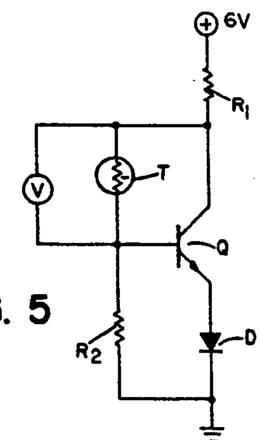


FIG. 5